

Driver Linac Beam Dynamics

R&D Category:
Driver Beam Dynamics and Simulations

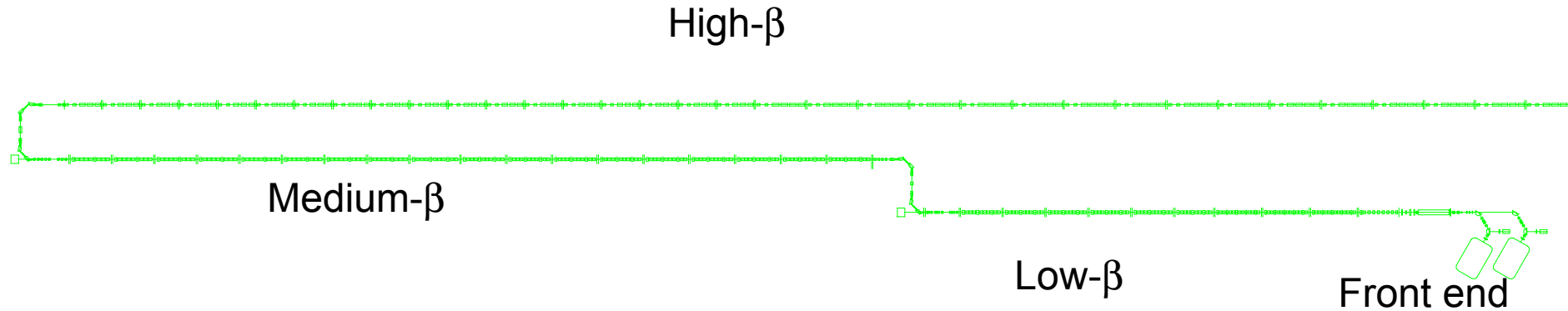
Petr Ostroumov

RIA R&D Workshop, August 26-28, 2003

Argonne National Laboratory
Operated by The University of Chicago
for the U.S. Department of Energy



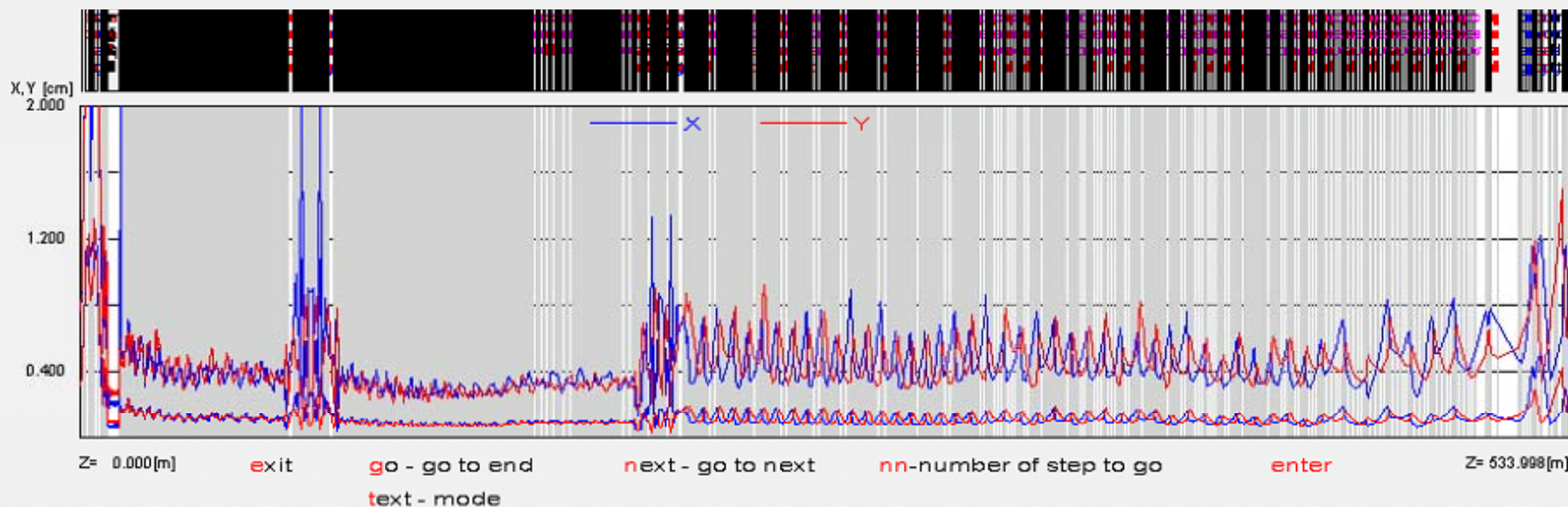
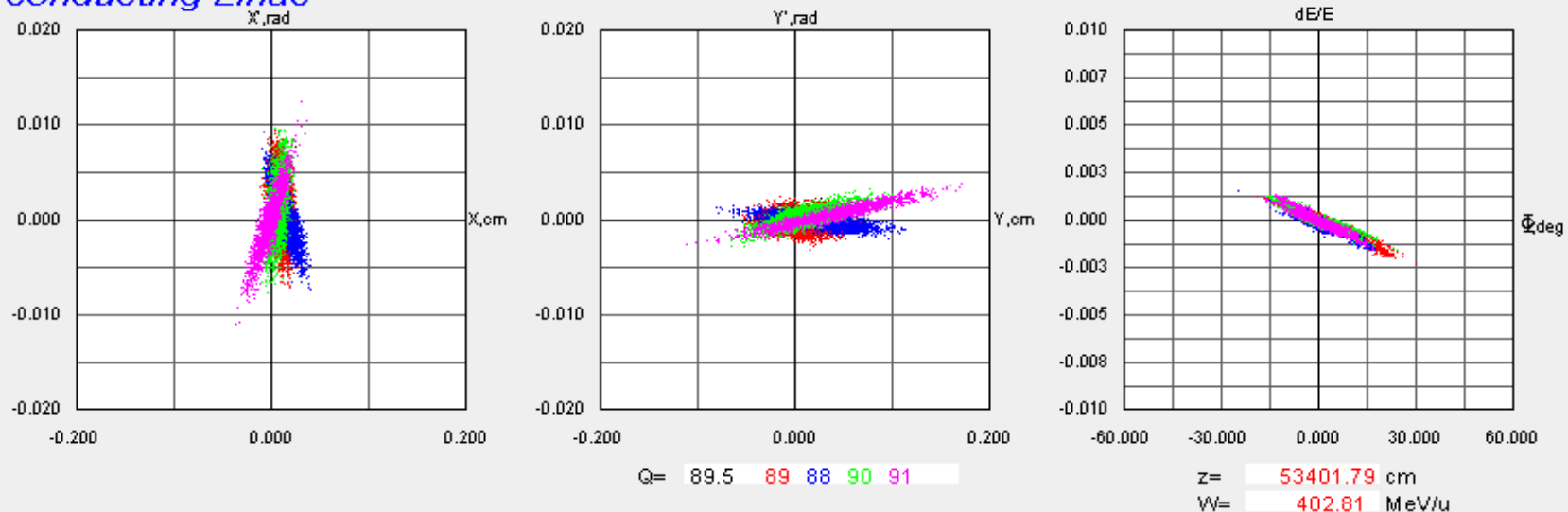
Beam Dynamics in the RIA Driver Linac



- The main concept was formulated in 1999.
- R&D work has been concentrated on two main topics:
 - 1) Modification and improvement of the physics design of the driver linac using existing standard codes and TRACK.
 - 2) Development of an end-to-end simulation code.

We have completed the development of the computer code TRACK: ECR-to-Target BD simulations.

- Integration of particle trajectories of multi-component ion beams in 6D phase space;
- Electrostatic, magnetostatic and electromagnetic fields of all RIA elements are obtained from 3-dimensional external codes.
- Misalignments and random errors are included. Beam steering procedure is applied in the linac with misaligned components. (see talk by E. Lessner)
- Space charge of multiple component ion beams is obtained from 3D Poisson equation.
- Beam passage through stripping foils&films is included; SRIM data of particle distribution in 6D phase space is incorporated.
- Parallel computing on multiprocessor computer cluster JAZZ at ANL. Simulation of total 10^7 particles in 15 hours is demonstrated.
(see talk by B. Mustapha)

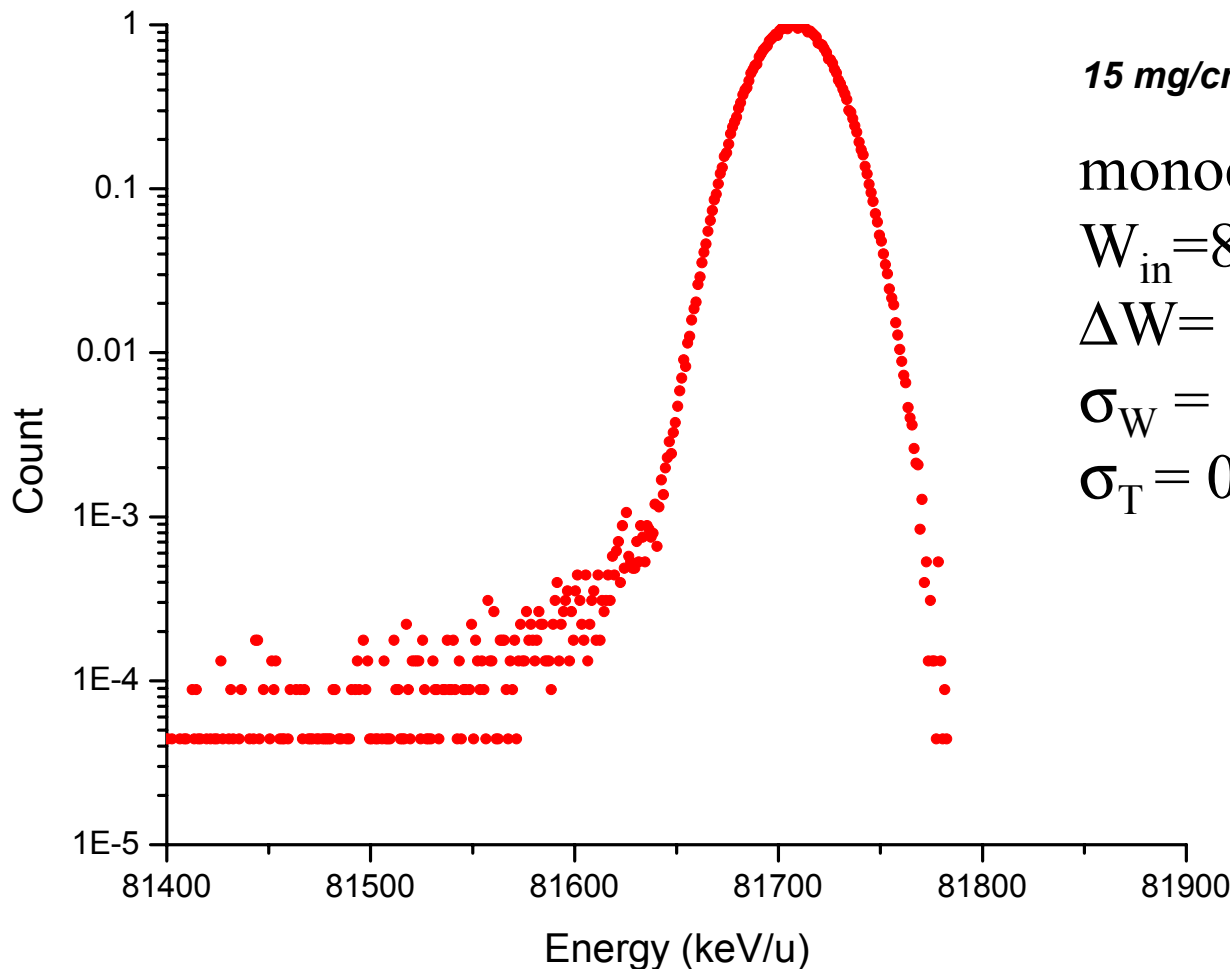


Design modifications:

- An experimental confirmation of acceleration of multi-q beams beams.
- Two charge state heavy-ion beam from the ECR.
- Compact linac lattice which minimizes emittance growth.
- Steering and higher order components of defocusing electric fields.
Dipole coils combined with solenoids.
- Several types of parametric resonances in SC linacs.
- Stripper effects on heavy-ion beam parameters.
- Major contributors to the effective emittance growth are identified.
- Other minor mechanisms of the beam halo formation were found.
- Transport and matching of multi-q beams.
- Advantage of using lower frequency TSRs.
- Effective cleaning of beam halo.

SRIM results, 10^6 particles, elastic scattering

SRIM = Stopping Range of Ions in Matter
by J.F. Ziegler, J.P. Biersack and U. Littmark



15 mg/cm² Carbon foil

monochromatic input beam

$W_{in} = 85 \text{ MeV/u}$

$\Delta W = 3.29 \text{ MeV/u}$

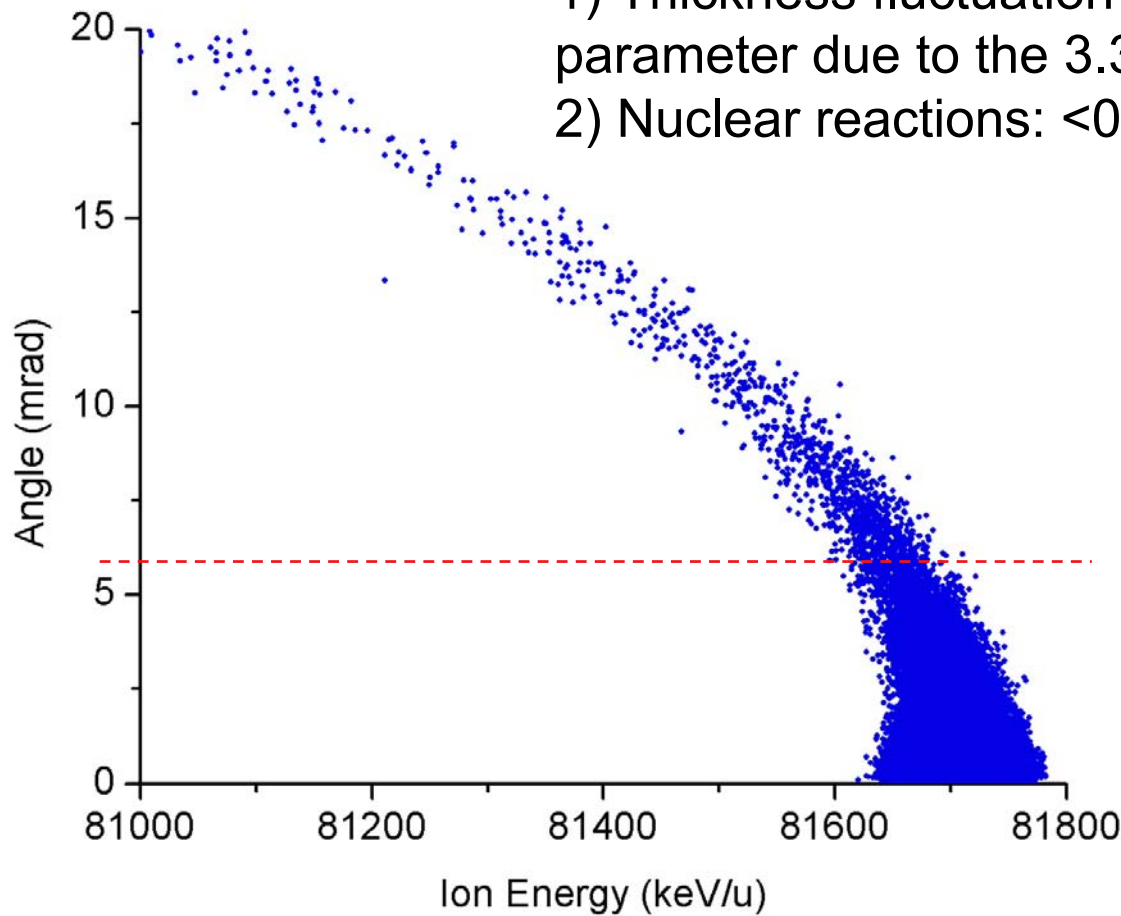
$\sigma_W = 17.6 \text{ keV/u}$

$\sigma_T = 0.5 \text{ mrad}$

Distribution in the energy-angle plane (elastic scattering)

SRIM results, 10^6 particles, angle = $\sqrt{x'^2 + y'^2}$

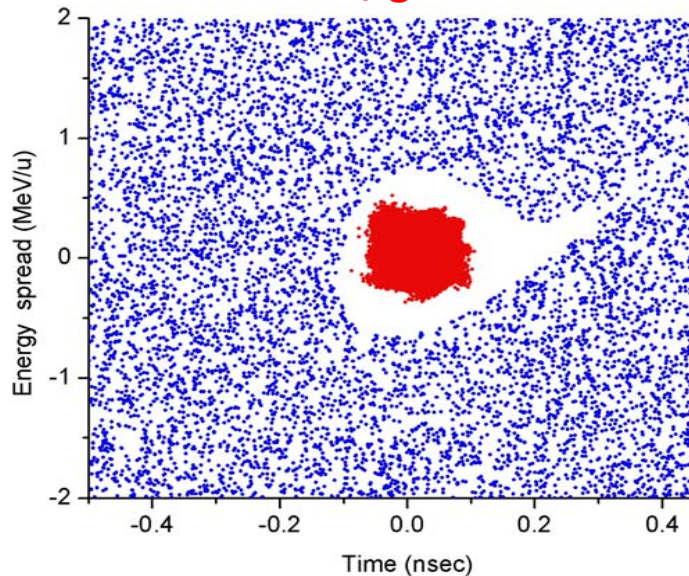
- 1) Thickness fluctuation is an important parameter due to the 3.3 MeV/u energy loss.
- 2) Nuclear reactions: <0.2% of ions, not included.



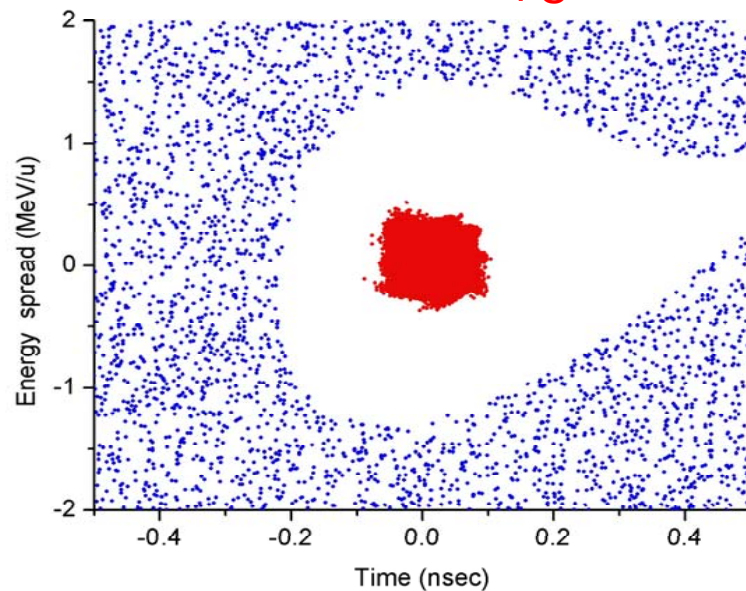
Consequences:

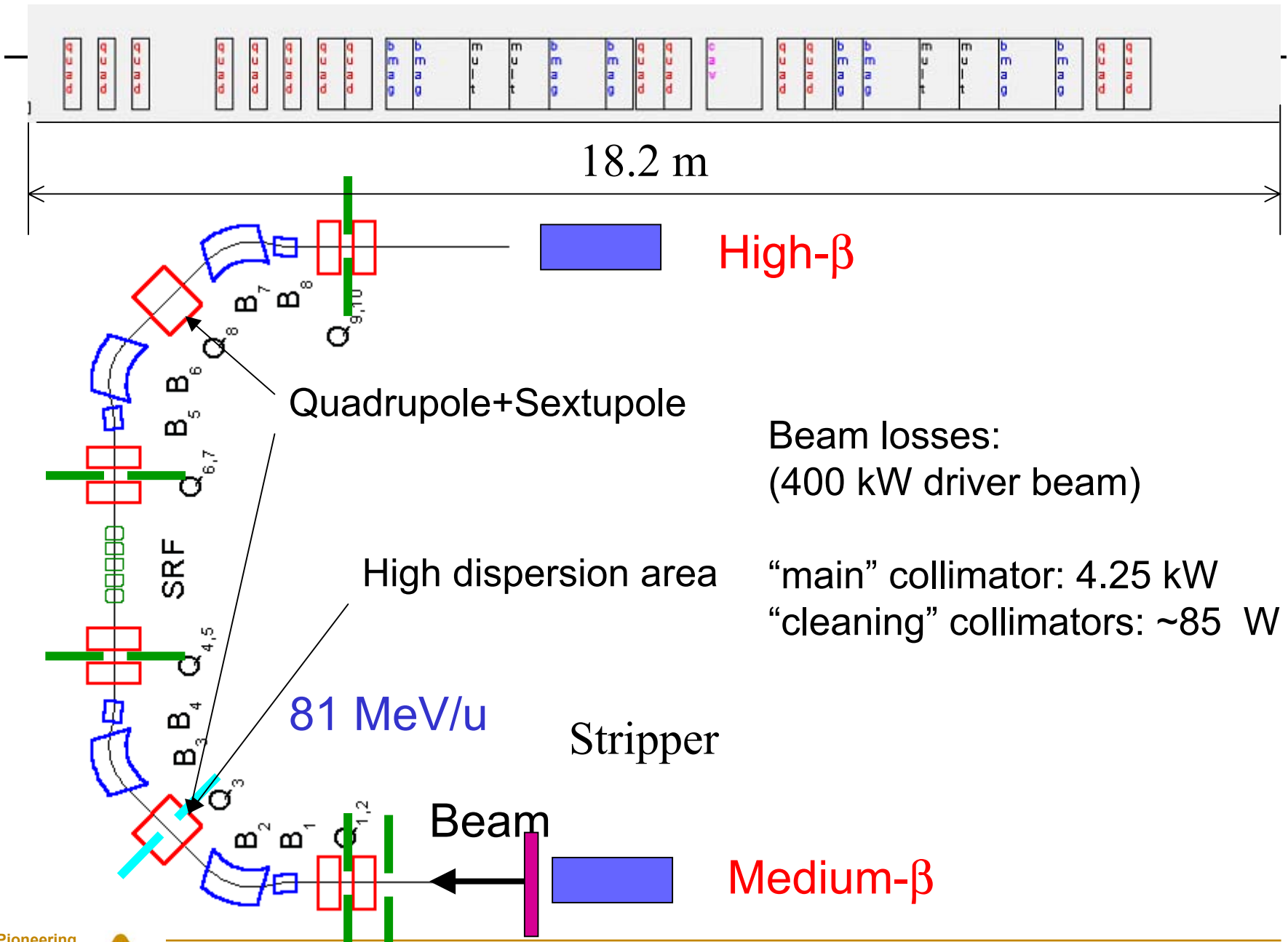
- Use lower frequency SC resonators – TSL in high- β : larger longitudinal acceptance.
- Collimate beam in the transverse phase space.

ECL, $\phi_S = -30^\circ$



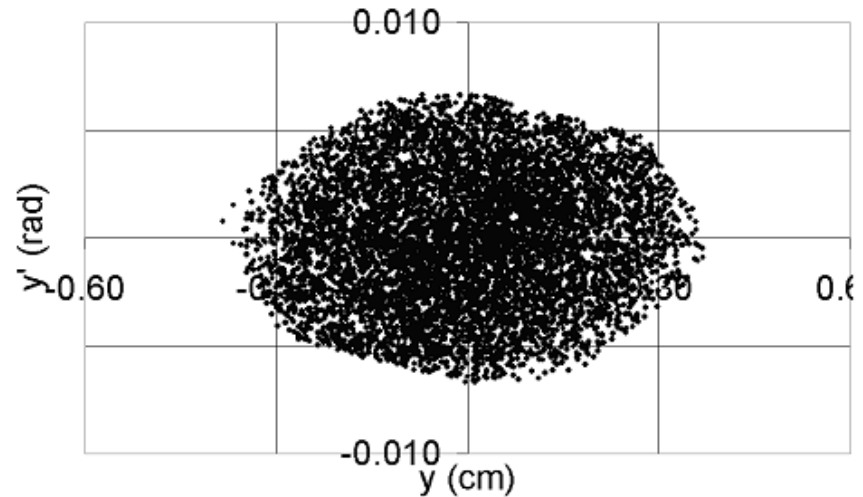
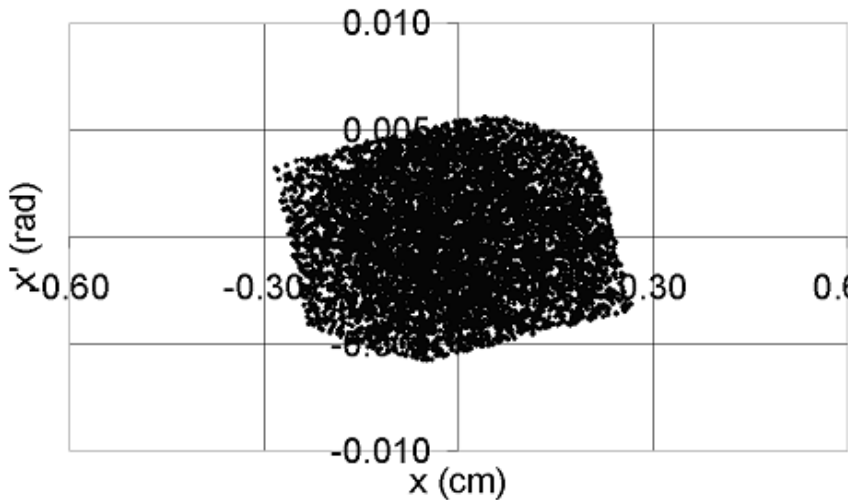
TSL, $\phi_S = -25^\circ$





Transverse acceptance with collimators

Slit opening = ± 10 mm



Transverse phase space

Beam rms emittance

0.2π mm mrad

Acceptance of the MTS
10 mm slit opening

9.0π mm mrad = 45·rms emittance

Beam loss calculations

Relative beam losses in high- β section:

- a) Nuclear reaction products are not included.
- b) Foil thickness fluctuation is $\pm 5\%$.
- c) Rf errors: $\pm 0.5^\circ$, $\pm 0.5\%$, 100 randomly seeded linacs.
- d) Beam halo collimation in designated areas at the post-stripper MTS has been applied.

| δW (keV/u), rms width | Elliptical cavity linac | Triple spoke linac |
|-------------------------------|-------------------------|--------------------|
| 17.6 (SRIM) | No | No |
| 53 | $6 \cdot 10^{-5}$ | No |
| 88 | $2 \cdot 10^{-4}$ | No |

- Preliminary data of the beam energy distribution after the stripping foil shows appreciable discrepancy between the measurements and SRIM calculations.
- Estimated beam losses due to the nuclear reaction products: less than $n \cdot 10^{-6}$ (John Schiffer). Detailed studies are required.

Conclusion, needs for future work

- There is a solid “reference design” of the driver linac:
 - No beam losses except in the designated areas (nuclear products are not included);
 - Complete study of this design by end-to-end simulation using the TRACK and other available codes is necessary.
- Future studies will be devoted to further optimization of the driver accelerator design, which will eventually result in better performance of the driver linac.
- The following work is currently in progress:
 - Comparison of different options of the driver linac.
 - Development of specifications to the steering magnets.
 - Studies of beam parameters sensitivity to errors/misalignments/strippers.
 - Beam collimation, cleaning of 4-dimensional beam emittance, and design of the shielding in the post-stripper transport systems.
 - Dynamics of radioactive products in the linac.

Conclusion (cont'd)

- Experimental study of particle energy and angle distribution after the stripping of 85 MeV/u uranium. Preliminary data of the beam energy distribution after the stripping foil shows appreciable discrepancy between the measurements and SRIM calculations.
- Some modifications of the TRACK version for parallel computing are required.
- Perform end-to-end simulations of all new options of the driver linac and compare beam quality with the reference design.
- Complete the TRACK code manual and distribute among the research groups working in this field.